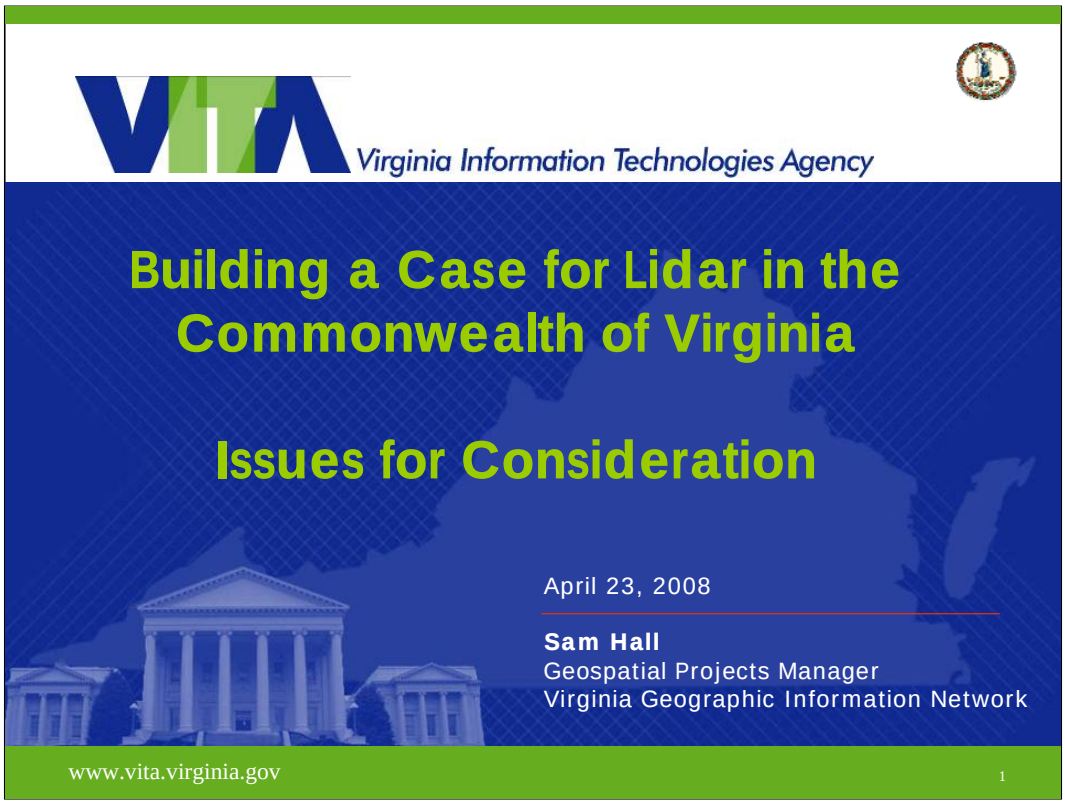
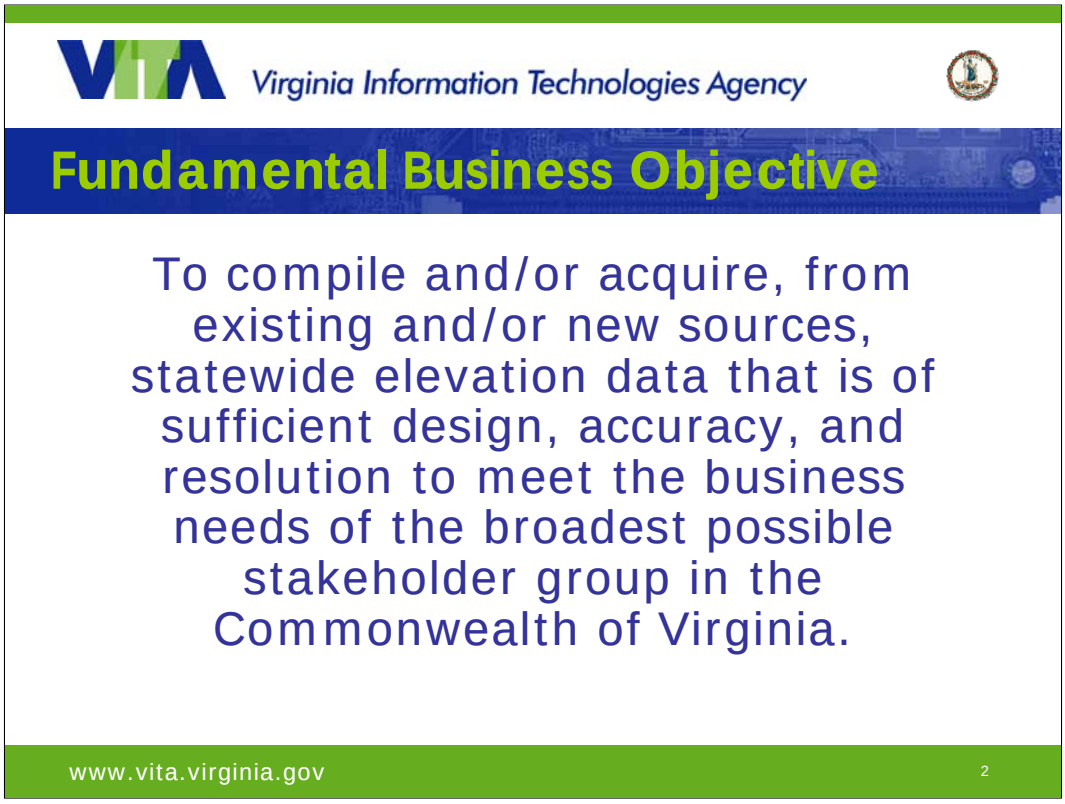


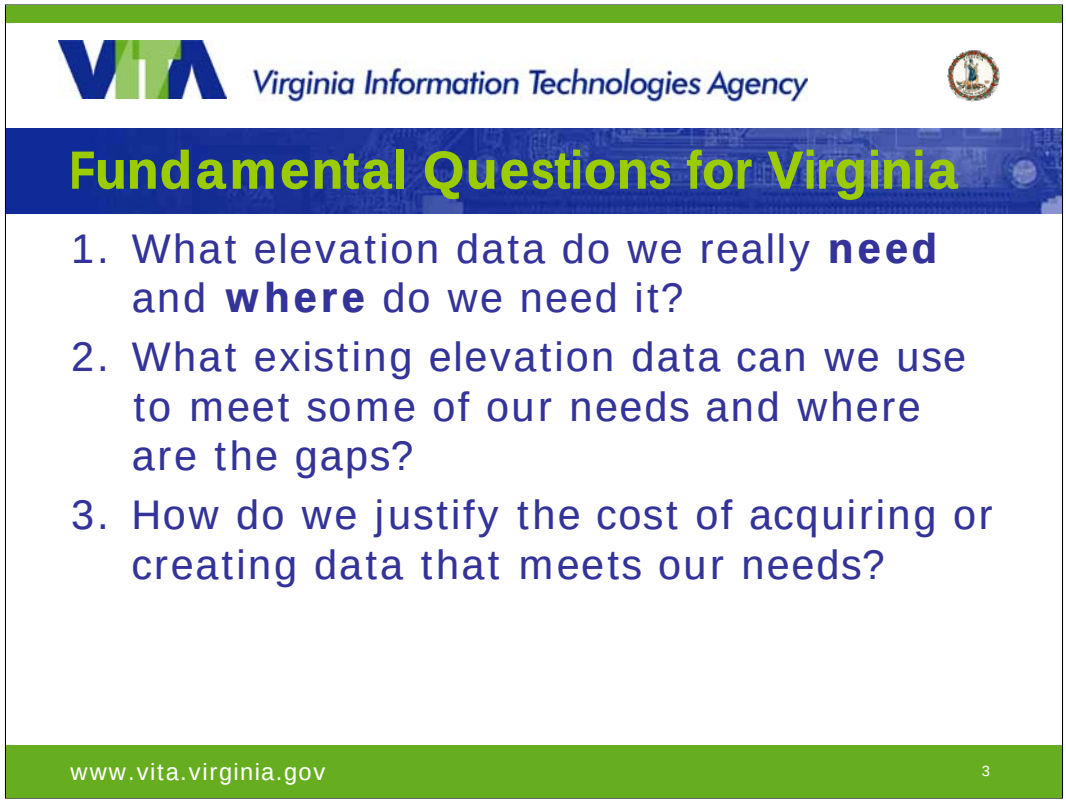

The Virginia Geographic Information Network (VGIN) is developing a cost/benefit analysis for the collection of lidar data in the Commonwealth. We have learned that there are many factors to consider when collecting lidar.

Building a cost/benefit analysis for an effort entails documenting business objectives, documenting the current state (or “as is”), identifying and quantifying costs and both tangible and intangible benefits, examining alternatives for reaching desired goals, and ultimately analyzing the numbers to determine which alternative makes the most financial sense.

Because there many competing interests in elevation data across the Commonwealth, and because the cost of lidar acquisition and processing is very high, it is important to thoroughly explore as many options as possible while trying to reach our goals.




Our business objective is to compile and/or acquire, from existing and/or new sources, statewide elevation data that is of sufficient design, accuracy, and resolution to meet the business needs of the broadest possible stakeholder group in the Commonwealth of Virginia. These stakeholders include local, state, and federal government agencies, non-profit and non-governmental organizations, the private sector, and private citizens.




We already have some elevation data for Virginia. This existing elevation data meets many stakeholder business needs. However, there are clear shortcomings in our current elevation data holdings that make many of our critical tasks impossible to complete.

One example of a critical task that we cannot accomplish with our current elevation data is modeling sea level rise due to climate change. Mean sea level is expected to rise by a minimum of 2.3 feet over the next 100 years. This rise will certainly wreak havoc on both man-made infrastructure and natural resources (such as wetlands) in Virginia's coastal zone. Our best elevation data for the coast is at a resolution that will support the development of accurate 2-foot or 4-foot contours, which is too generalized to support accurate modeling of inundation from sea level rise. Therefore, we need higher resolution elevation data for coastal Virginia.

Taking the sea level rise modeling issue a step further, can we demonstrate that the benefits of acquiring lidar data that will support the modeling outweigh the costs? What costs, either present or future, might we reduce or avoid by having an accurate model of sea level rise inundation?

There are many other examples.


Lidar is a technology. The products of lidar are what we really care about. For example, do we want:

•High-resolution bare earth digital elevation models? What resolution do we really care about? Do we want to be able to model a 3-inch rise in sea level, or just estimate damages from a category 3 hurricane?

•Tree canopy heights and densities? At what resolution?

•To be able to see fault lines, evidence of mining activity, and other relatively small geological features?

•The ability to map minute changes in topography associated with microhabitats of our imperiled species?

•The ability to model our cities and towns, including buildings, curbs, and power lines?

The answers to these questions really matter when you examine the costs and benefits of collecting lidar data. And, considering the tremendous cost of lidar relative to other sources of elevation data, it's a good idea to get it right the first time. Most experts say that a good bare earth elevation model derived from lidar has a lifespan of about 10 years for many applications. North Carolina mapped their coastal zone with lidar at 5-meter post spacing for their flood plain mapping program, but they've now realized that they need higher resolution data for other applications.

# The Current State

What readily-available elevation data currently exists for Virginia?

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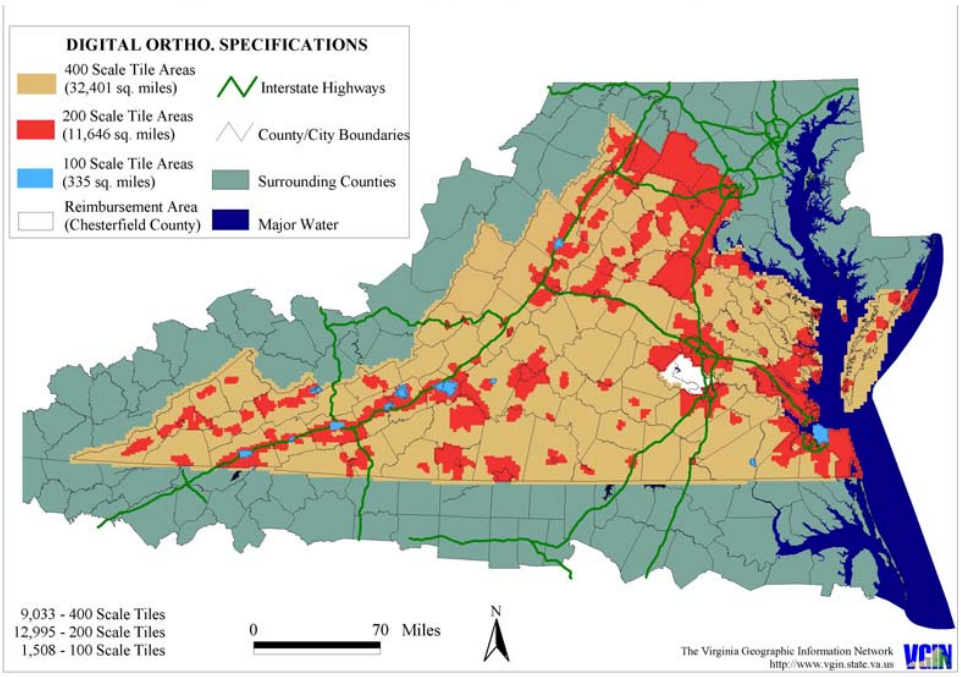
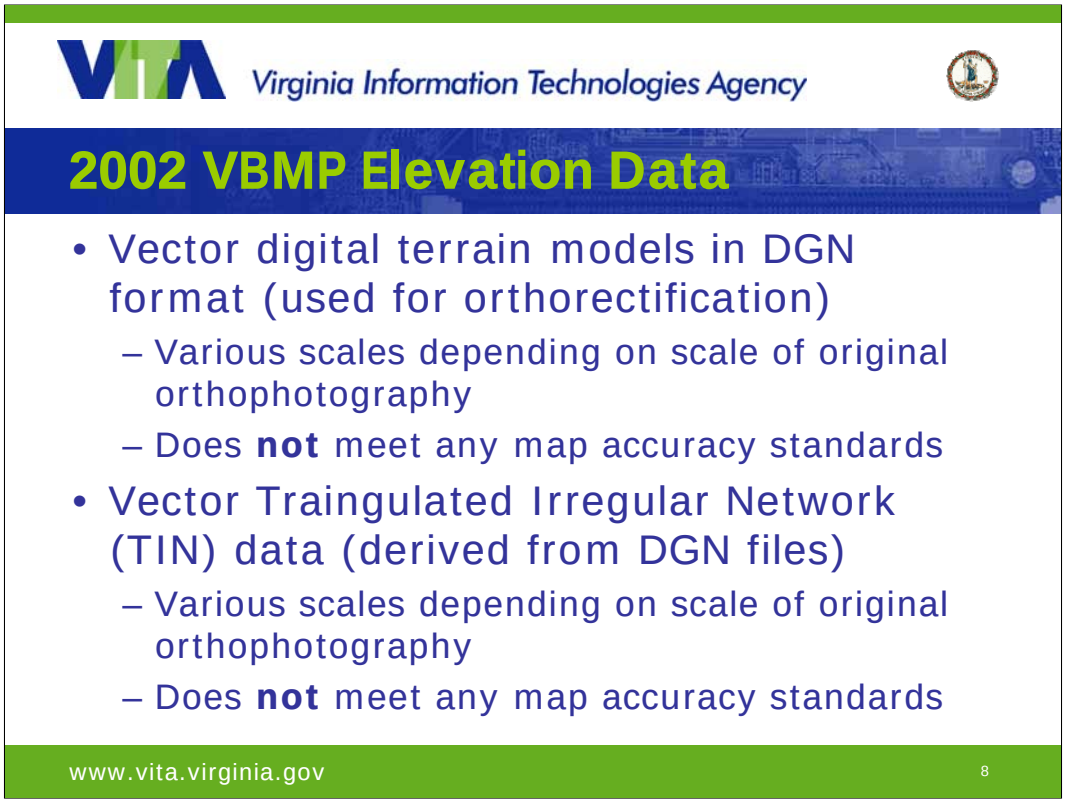
# What Elevation Do We Have Now?

- VA Base Mapping Program elevation data
  - 2002 elevation data
  - 2006/2007 elevation data
- Lidar in a few areas
- National Elevation Dataset (NED)
- Shuttle Radar Topography Mission
- Survey-grade topographic maps
- Some bathymetric data
- Other minor datasets

# 2002 Orthophotography Resolution

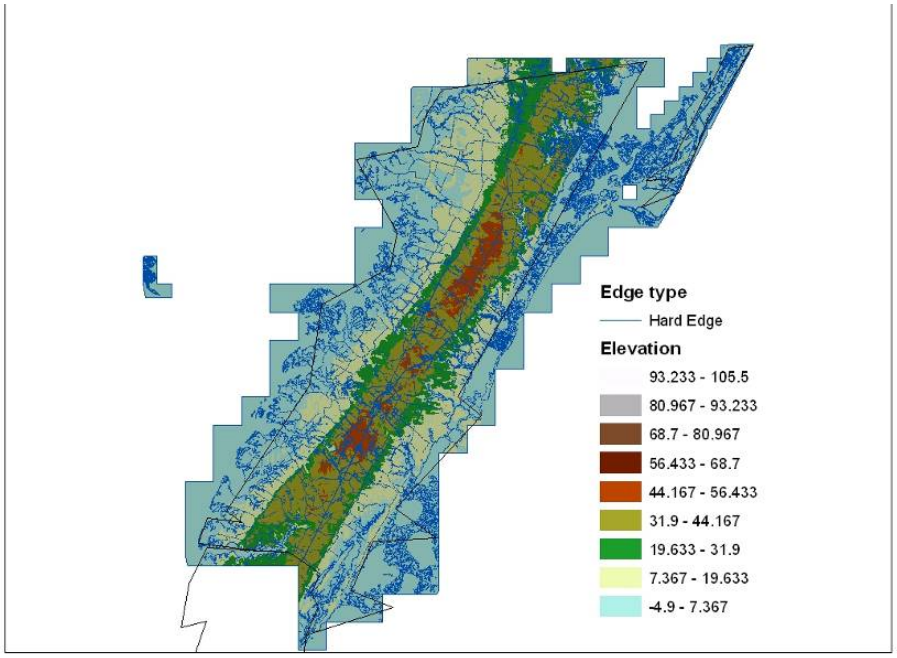



2002 Virginia Base Mapping Program (VBMP) elevation data is derived from the 2002 VBMP orthophotography. The scale of the elevation data for an area is dependent upon the scale/resolution of the aerial imagery that was captured for that same area. This slide shows the scale/resolution of the 2002 aerial imagery across the Commonwealth. The majority of the state was photographed at 1"=400', or 2-foot pixel resolution. Significant areas were photographed at 1"=200', or 1-foot pixel resolution. A small portion of the state was photographed at 1"=100', or 6-inch pixel resolution.




Several elevation data products were derived from the 2002 aerial photography. A vector-based digital terrain model (DTM) in Microstation DGN format was extracted from the imagery and was used for orthorectification. The scales of these DTMs coincides with the scale of the original photography (i.e. 1"=400', 1"=200', or 1"=100'). County-by-county ESRI TINs were later created from the DGN files. These TINs are available for download at

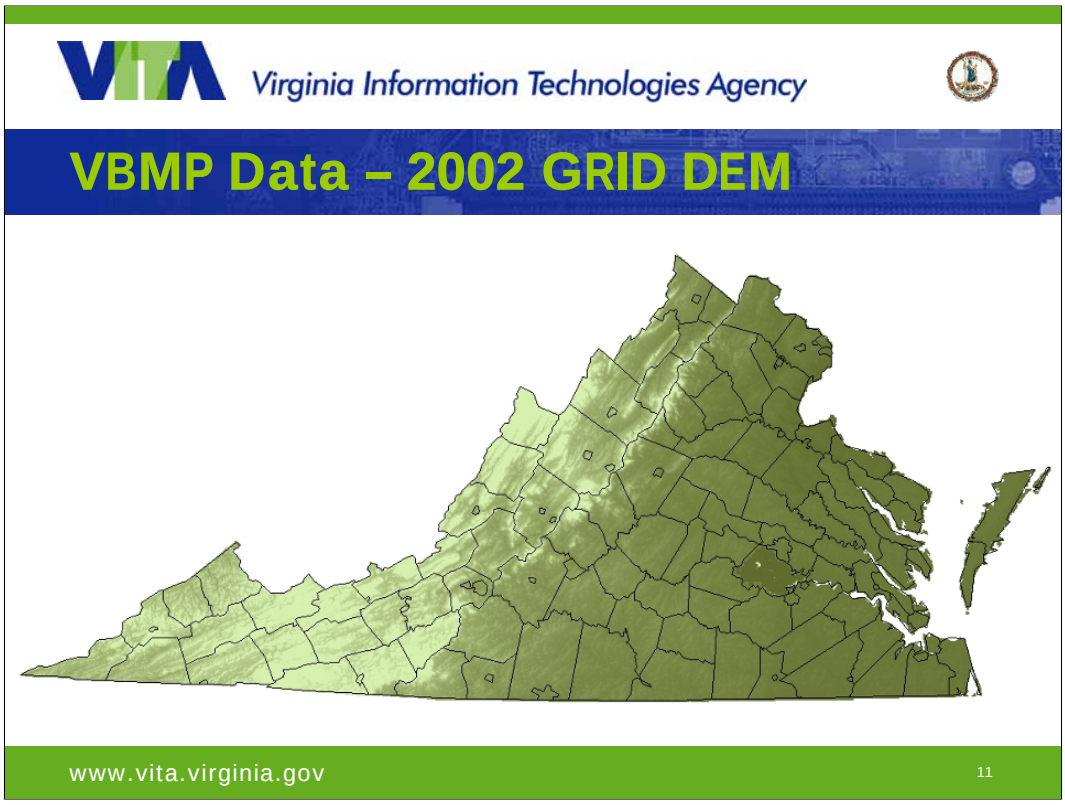
## 2002 TIN (Accomack County)



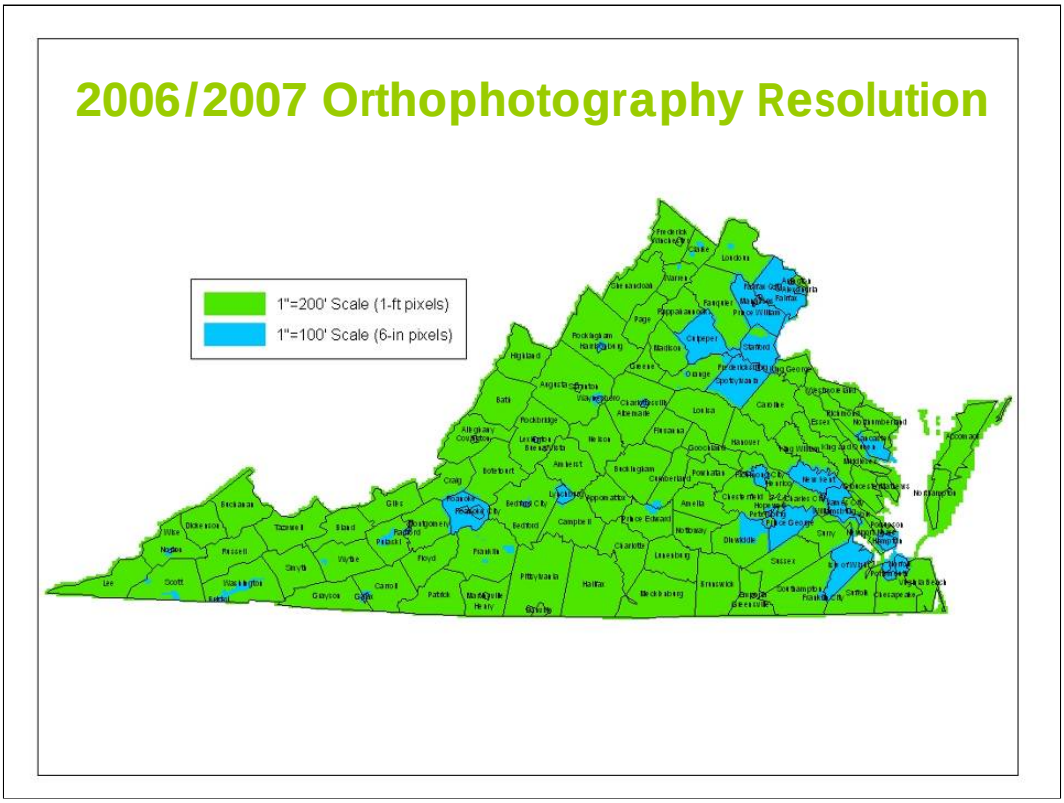

A product of the 2002 aerial imagery acquisition was the TINs that were used for orthorectification. These TINs do not meet any elevation data accuracy standards.

# 2002 VBMP Elevation Data (cont.)

- Bare earth digital elevation model (DEM) in ESRI GRID format
  - Derived from TINs
  - Various scales depending on scale of original orthophotography
  - Does **not** meet any map accuracy standards for contour generation




A bare-earth digital elevation model was created from the 2002 aerial imagery acquisition for ortho-correction of the photography. The DEM does not meet any elevation data accuracy standards and is for cartographic purposes only.




2006/2007 Virginia Base Mapping Program (VBMP) elevation data is derived from the 2006/2007VBMP orthophotography. The scale of the elevation data for an area is dependent upon the scale/resolution of the aerial imagery that was captured for that same area. This slide shows the scale/resolution of the 2002 aerial imagery across the Commonwealth. The majority of the state was photographed at 1"=200', or 1-foot pixel resolution. A significant portion of the state was photographed at 1"=100', or 6-inch pixel resolution.

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# 2006/2007 VBMP Elevation Data

- Vector digital terrain models in DGN format (used for orthorectification)
  - Various scales depending on scale of original orthophotography
  - **Meet** NSSDA map accuracy standards for orthorectification
- Vector Traingulated Irregular Network (TIN) data (derived from DGN files)
  - Various scales depending on scale of original orthophotography
  - Do **not** meet any map accuracy standards

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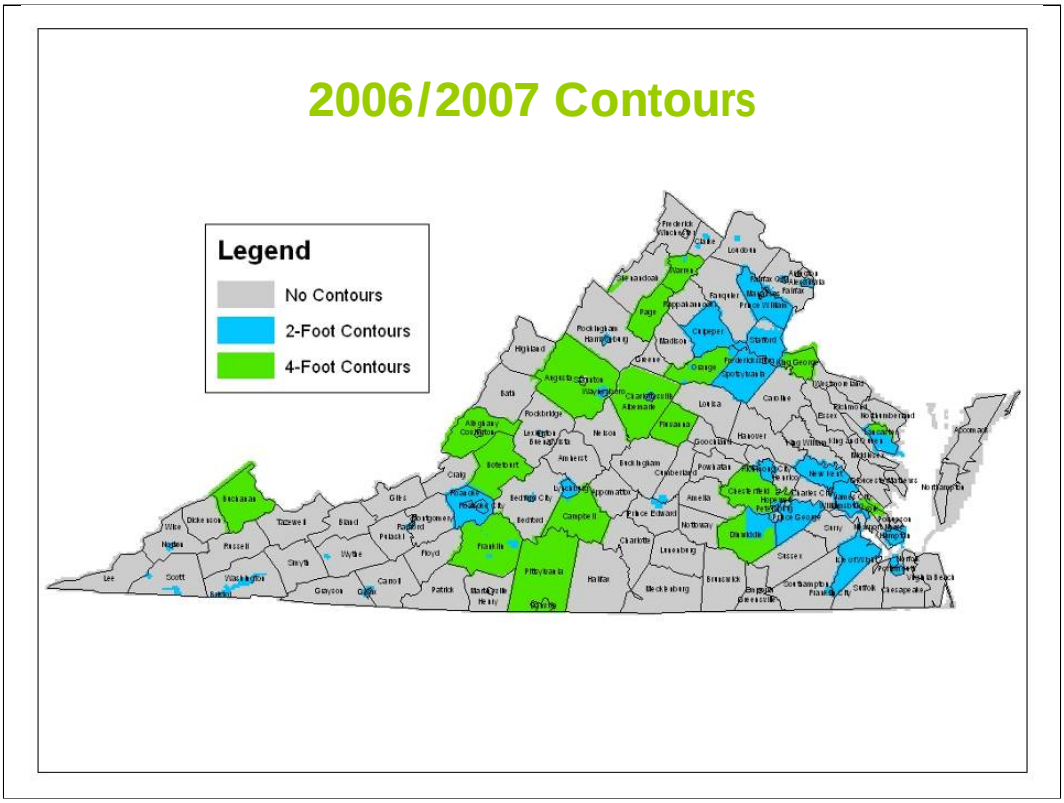
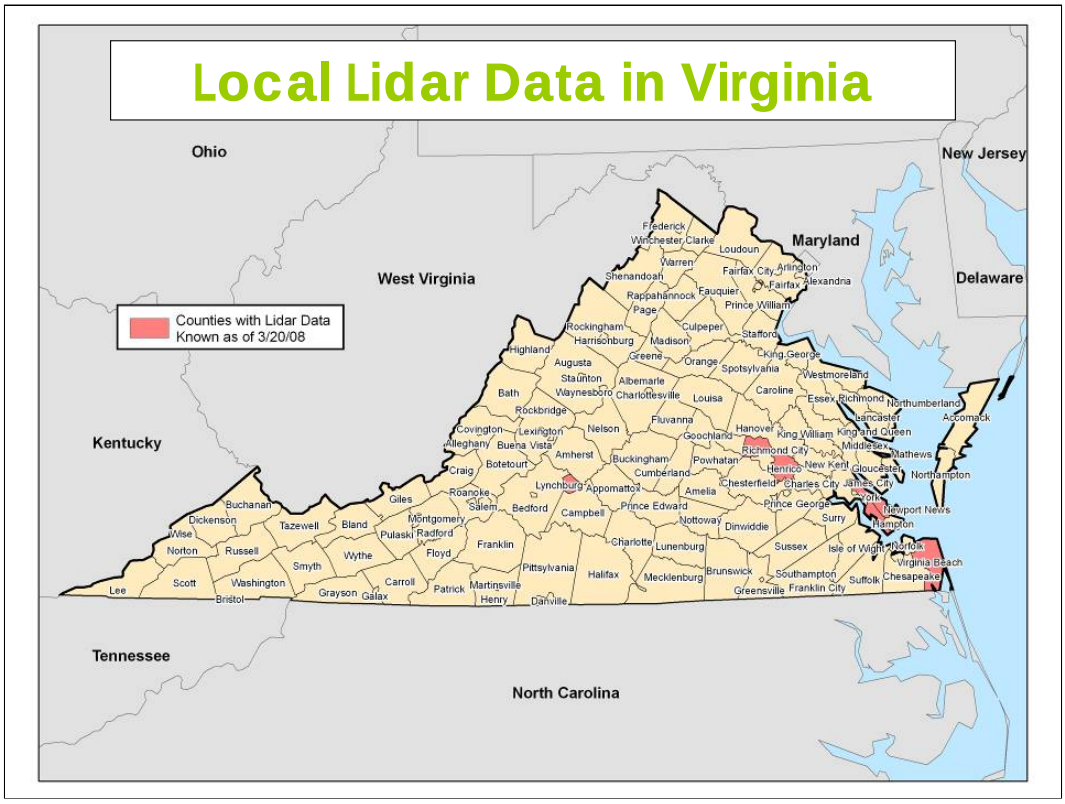
## 2006/2007 VBMP Elevation Data (cont.)

- Contours
  - Developed for specific localities that opted to purchase contours
  - Either 2-foot or 4-foot contours, depending on resolution of original orthophotography
  - **Meet** NSSDA standards for contours




This slide shows where both 2-foot and 4-foot contours were developed for the Commonwealth. Development of contours was offered as an upgrade option to localities for the 2006/2007 aerial photography acquisition cycle.




This slide depicts the Virginia localities that have collected their own lidar in the past.

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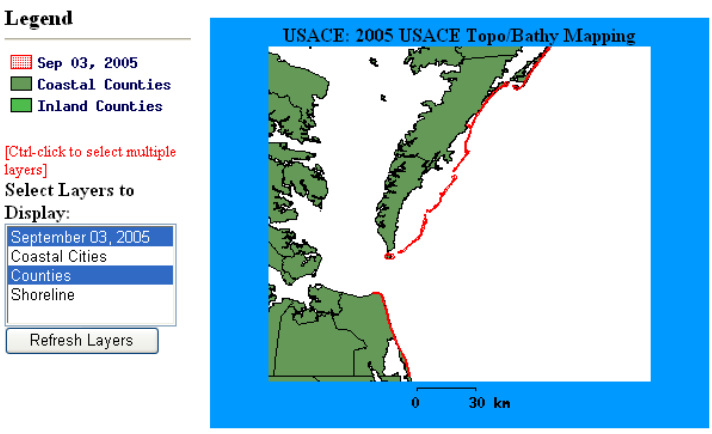
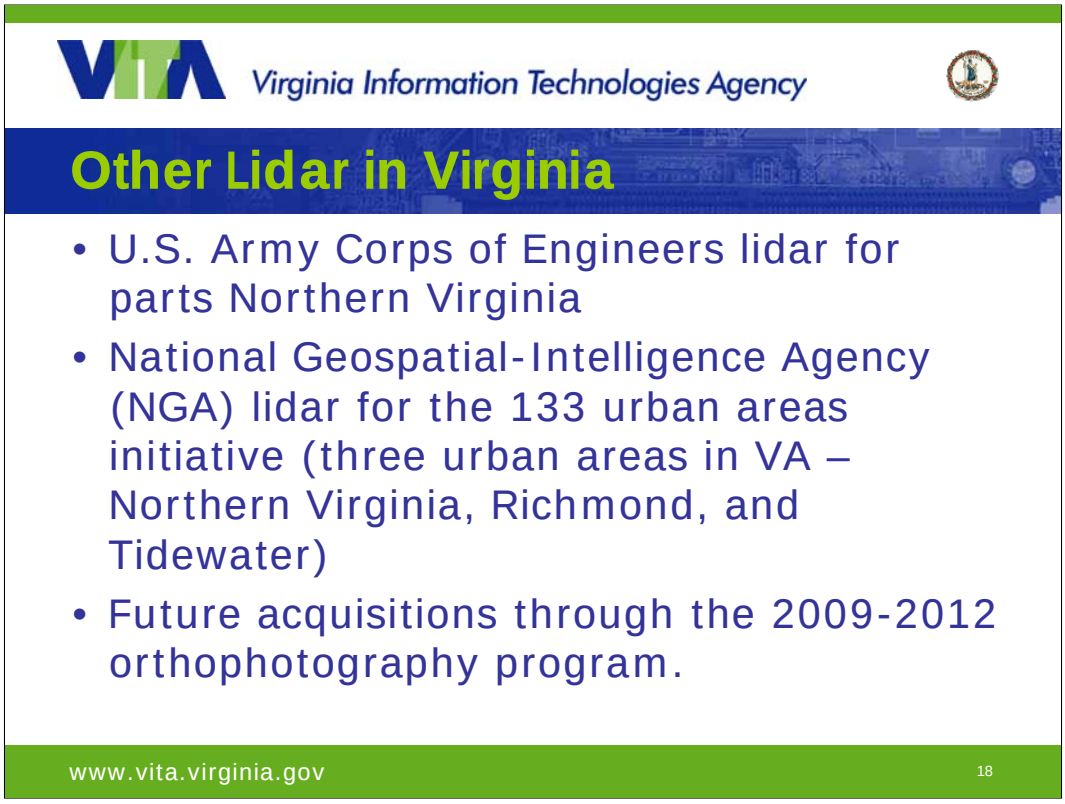
# NOAA Lidar in Virginia




**Source: http://maps.csc.noaa.gov/TCM/**
**More data is available from previous years.**



NOAA has collected lidar for some of Virginia's coast. More information can be found at http://maps.csc.noaa.gov/TCM/.




The U.S. Army Corps of Engineers and the NGA have collected lidar for limited portions of the Commonwealth.

Lidar will be an upgrade option in the 2009-2012 orthophotography acquisition cycle. State agencies, localities, the federal government, and others will have the ability to purchase lidar for specific areas of the state under the orthophotography contract vehicle. The contract will provide options for lidar that meets specific standards (e.g. FEMA-compliant lidar for flood plain mapping, NGA-compliant lidar for urban mapping).

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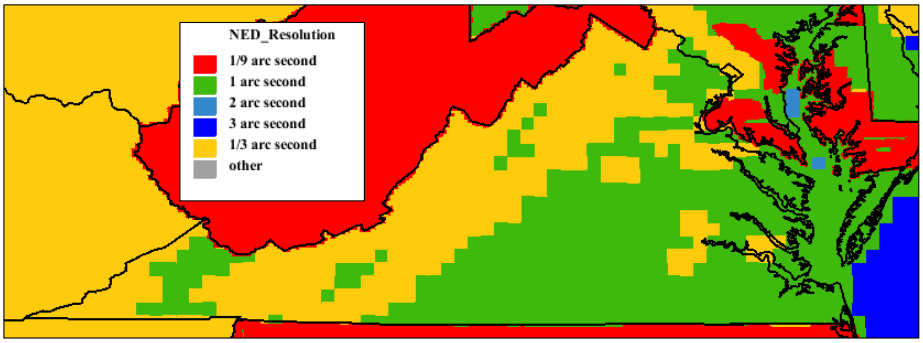
# NED Resolution in Virginia




- 1 arc second = 30m (green)
- 1/3 arc second = 10m (yellow)

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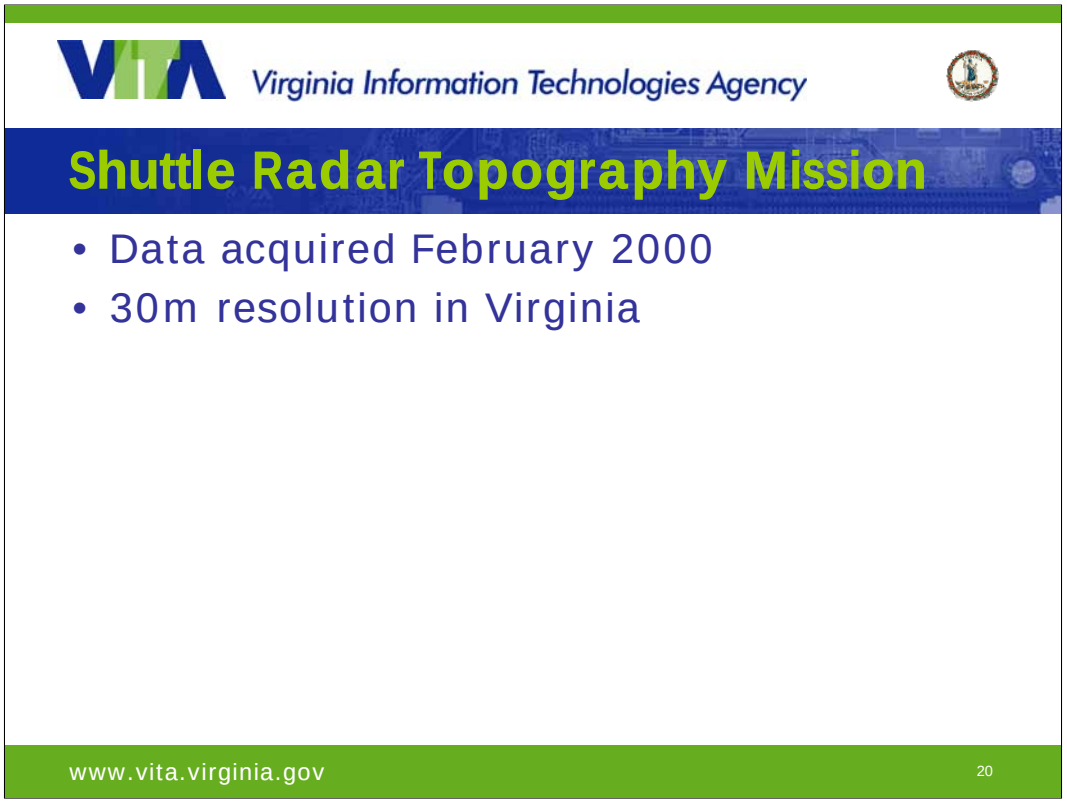
The USGS National Elevation Dataset (NED) is at a very course resolution.

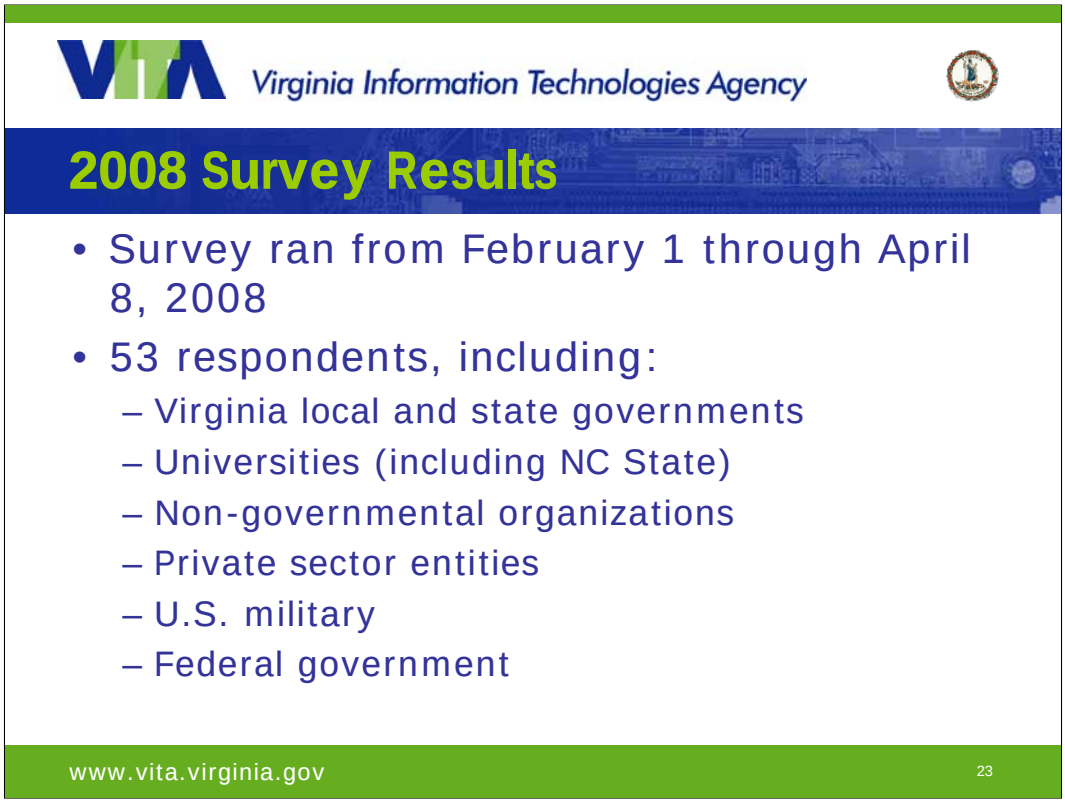



Shuttle Radar Topography Mission (SRTM) elevation data is also at a very course resolution (30m cell size).

# Our Business Needs

What elevation data do we need to effectively do our work?


There are three major categories of need for high resolution elevation data in the Commonwealth. These categories are: natural resource management, hydrologic modeling, and geologic mapping. There are many applications of high resolution elevation data within these three broad categories. Specific examples of these applications in Virginia are documented in the minutes from the August 2007 federal/state lidar summit at http://www.isp.virginia.gov/geopdf/LidarSummitMinutes.pdf.




VGIN conducted a short online survey to document existing elevation data in Virginia and ascertain statewide interest in lidar data. Full results of the survey are available at http://www.surveymonkey.com/sr.aspx?sm=DT6YE6rBxXRgLIqH7FE9FL0T8OD_2buotDAKLMjOnoKeM_3d.

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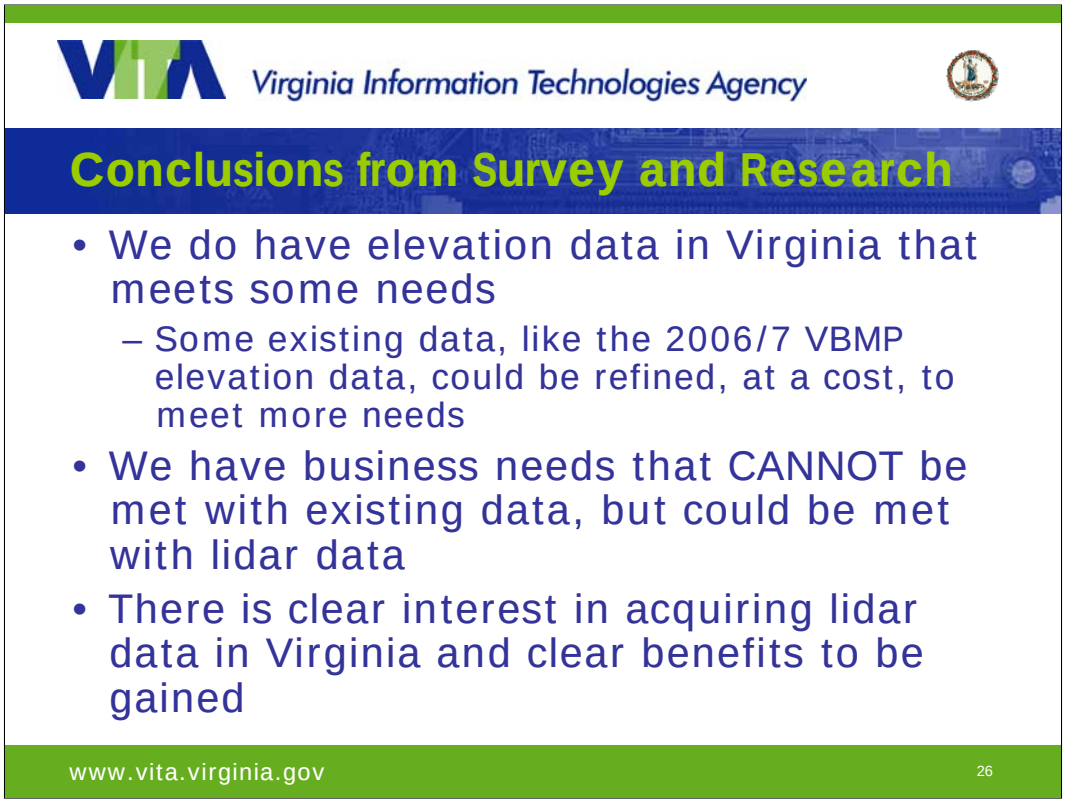
## 2008 Survey - Results of Interest

- 87% of respondents use some form of elevation data
- Of the users of elevation data, 74% said current elevation data does not meet business needs. Why?
  - 72% need higher resolution data
  - 58% need more accurate data
  - 47% need more current data
- 94% of respondents said lidar data would be useful to their organizations

# Full Survey Results

- Complete results of the survey can be viewed at the VGIN website:

  http://www.isp.virginia.gov/lidar.shtml




2006/2007 VBMP elevation data could be processed to enable creation of FEMA-compliant 2-foot or 4-foot contours across the state (depending on the scale of the original aerial photography that was captured). The elevation data could also be processed to create a hydrographically corrected GRID DEM. A hydrographically correct DEM can be used for hydrologic modeling because the DEM will accurately model how water flows on the surface of the land.

The 2007/2007 VBMP elevation data is lower resolution than is required for modeling sea level rise inundation. In addition, the data only depicts bare earth elevation, so applications such as tree canopy studies and urban corridor analyses are not possible.

# Lidar Specifications

What factors must be considered in designing a lidar acquisition to ensure we get what we need?

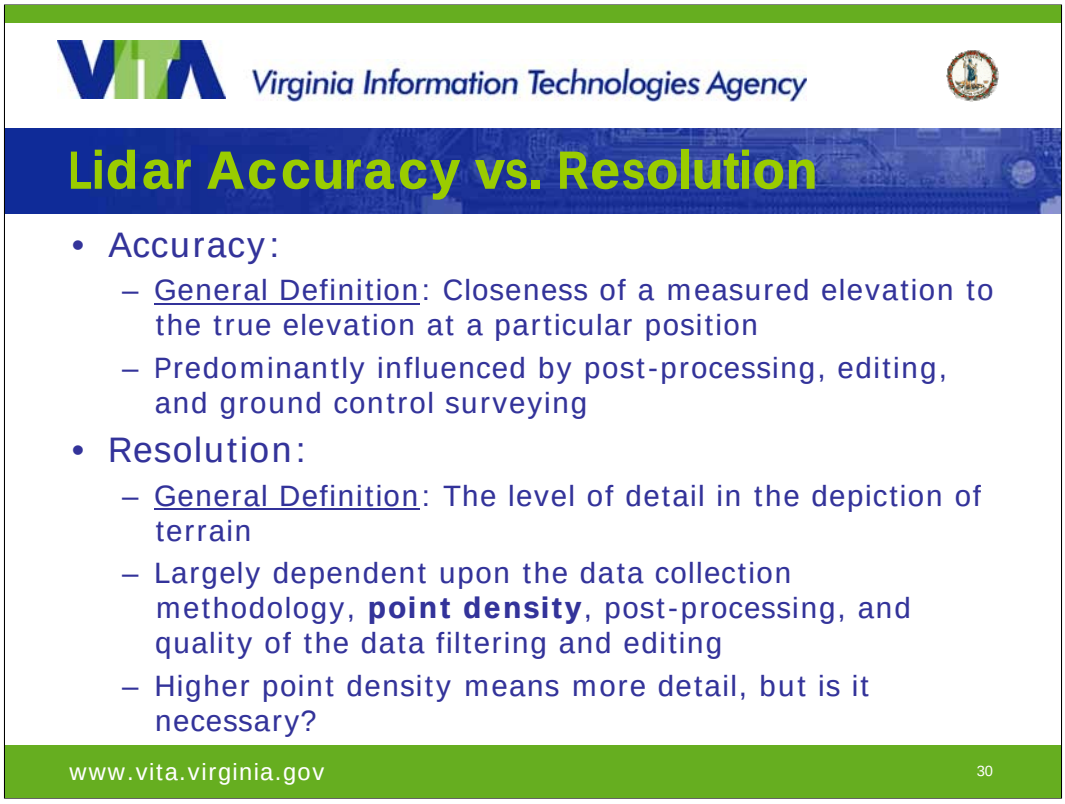
# Questions to Be Answered

- WHERE do we need lidar data collected?
  - What are our geographic priorities?
- WHAT specification do we use? Accuracy, resolution, and desired products are important factors.
- HOW do we quantify benefits and justify costs?
- HOW do we fund an acquisition?
  - WHO can help?

# Review of Lidar Basics

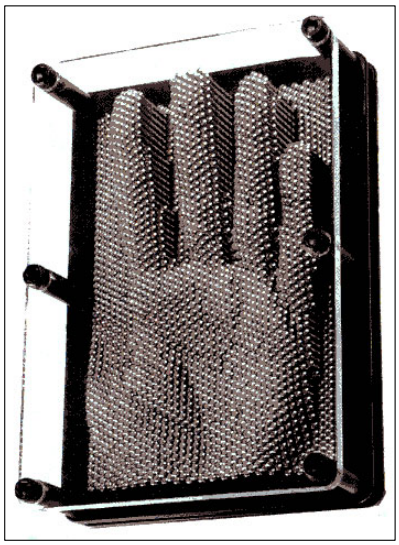
- If you are not familiar with the basics of lidar, please review the brief “Lidar 101” video available at:

  http://www.isp.virginia.gov/lidar.shtml

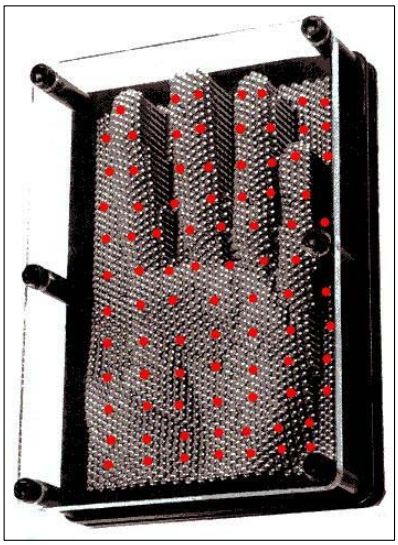



Accuracy, resolution, and desired data products are three most important factors to consider when developing a lidar specification.

# Accuracy and Resolution



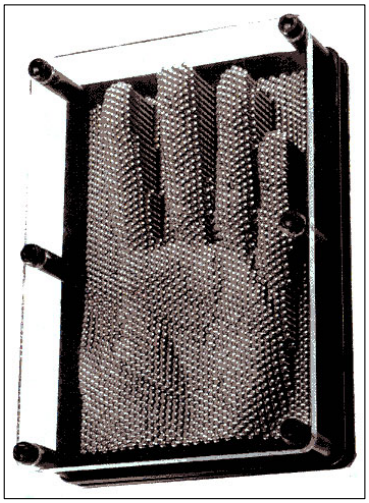
vs.



**Imagine each pin in the picture above is a high-accuracy lidar return. Lots of pins means high resolution.**

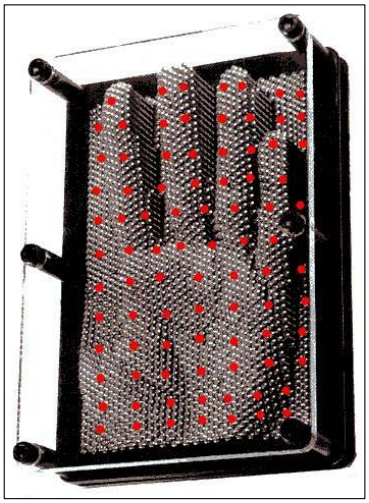
**Now imagine each red dot is a lidar return. The data may be no less accurate, but it is of lower resolution because it has a lower point density.**

# High Accuracy, High Resolution

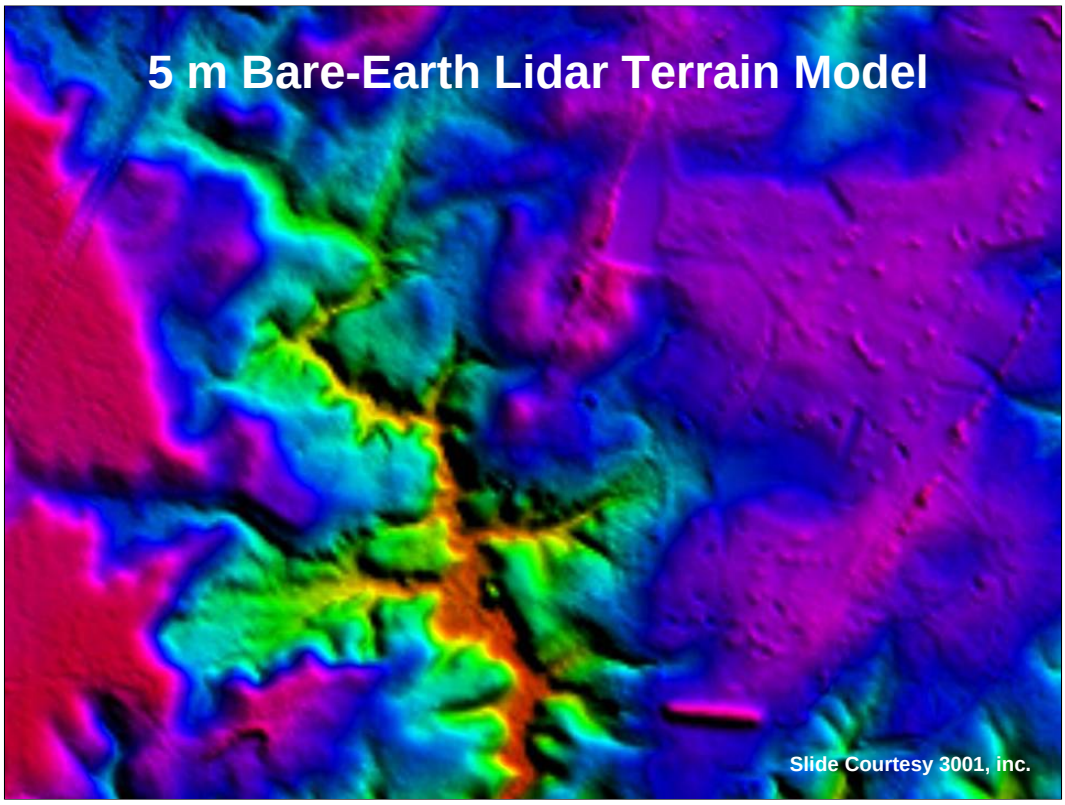


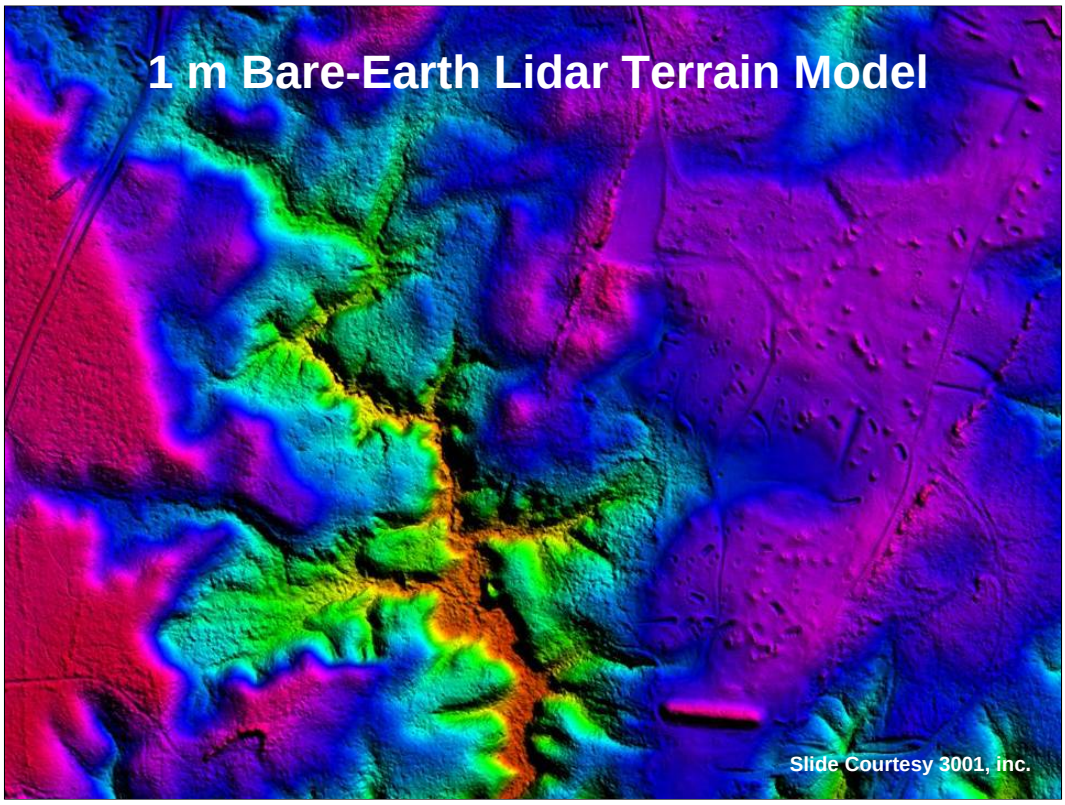
- Accurate and highly detailed depiction of terrain
- Can detect minute elevation changes, small topographic features, and edges of features very well
- Very expensive to collect and process
- HUGE datasets

# High Accuracy, Moderate Resolution



- Accurate, but less detailed
- Does not depict subtle elevation changes, small topographic features, and edges as well as higher resolution data
- Less expensive to collect and process than higher resolution
- Requires less storage space than higher resolution data (but still very large data sets)


5 m Bare-Earth Lidar Terrain Model
Slide Courtesy 3001, inc.


1 m Bare-Earth Lidar Terrain Model
Slide Courtesy 3001, inc.

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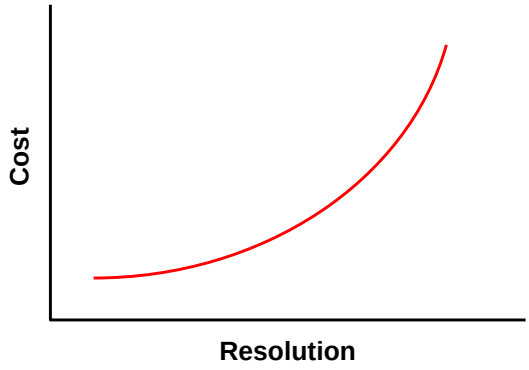
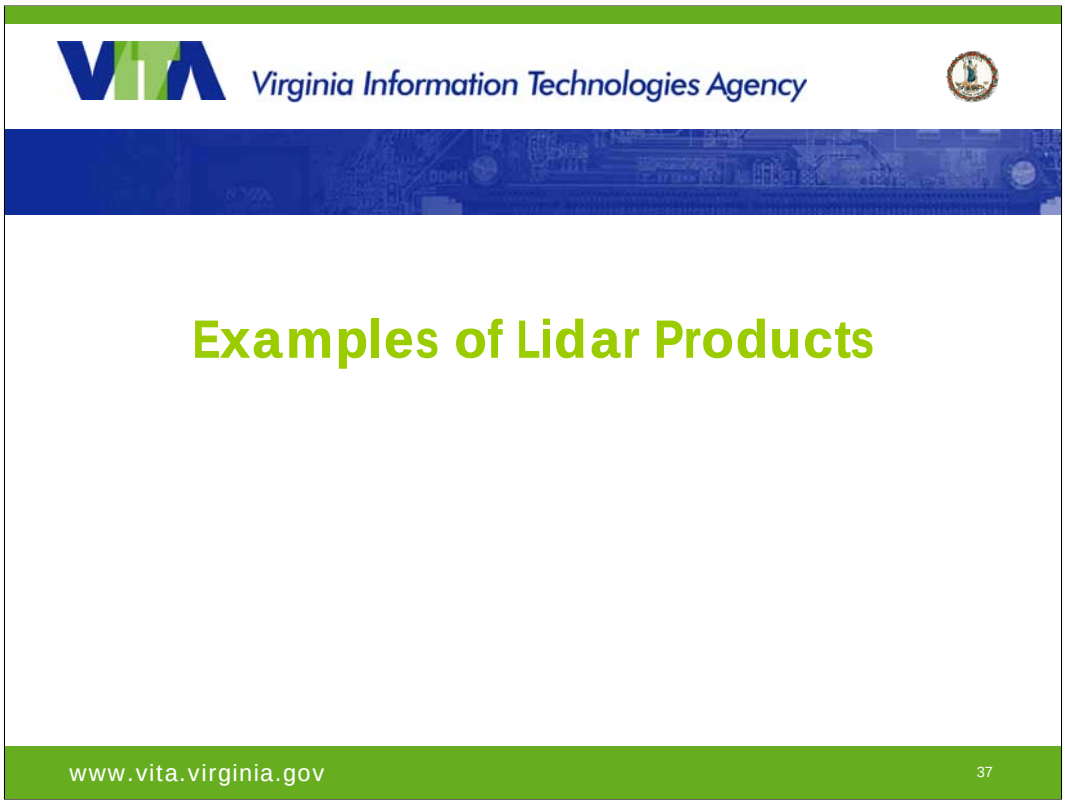
# Cost vs. Resolution

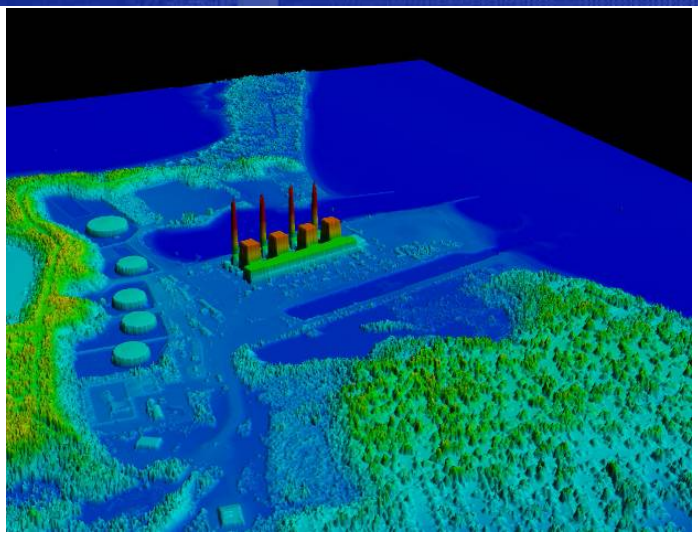



- Higher resolution means higher cost
- Cost is measured in acquisition, processing, and **storage, distribution, and use of data**
- What trade-offs between coverage, resolution, and cost are we willing to make?

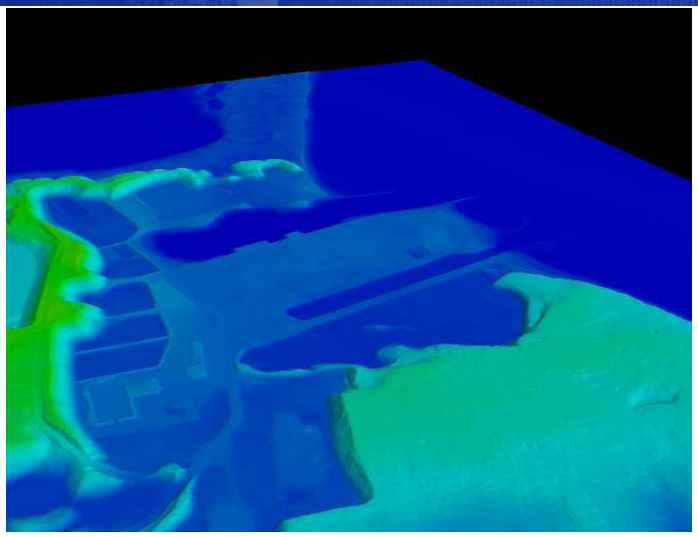



There are many products that can be derived from lidar, but it is critical to understand how the products will be used and the costs associated with generating the products. Following are some examples of elevation datasets that can derived from lidar. Consider the tradeoffs between resolution, accuracy, and data storage requirements for each of the products. Also consider the costs associated with generating each of these products; creating each product requires costly data processing and data management.

# Full Point Cloud Surface Model



# Bare Earth Model



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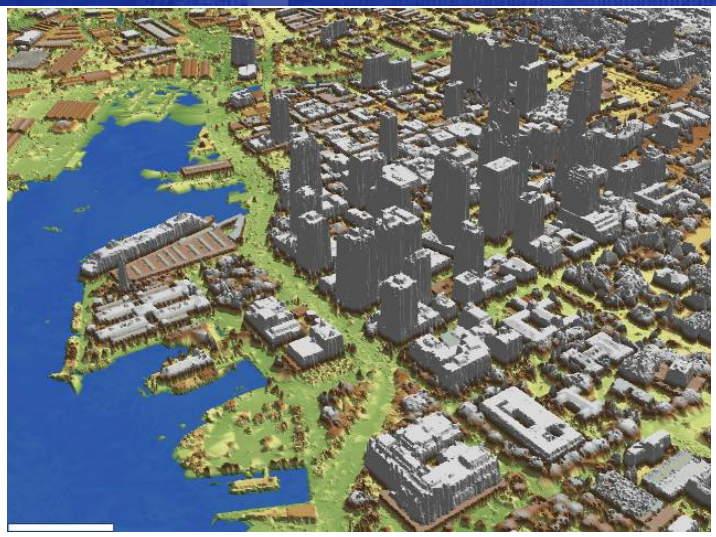
# Cityscape Surface Model



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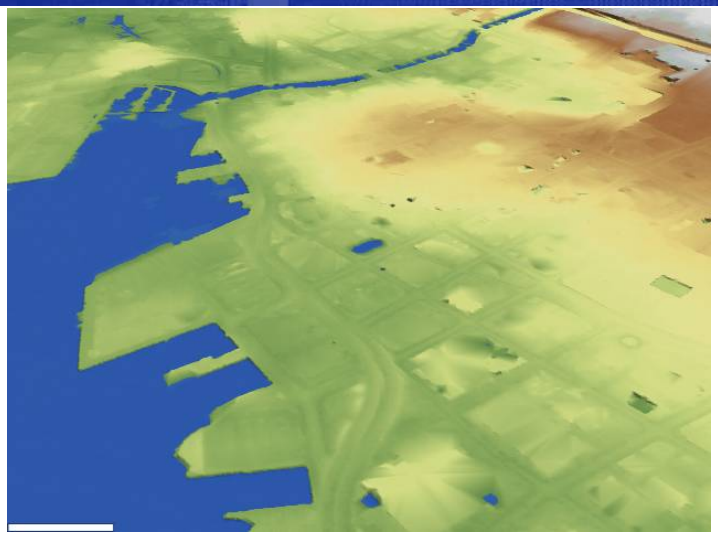
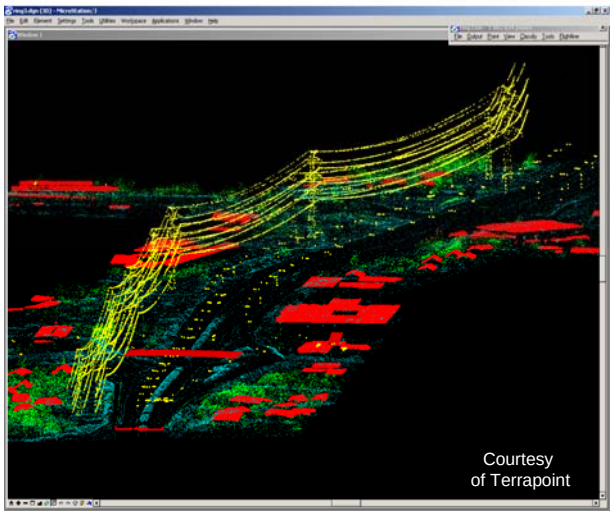
# Cityscape Bare Earth Model



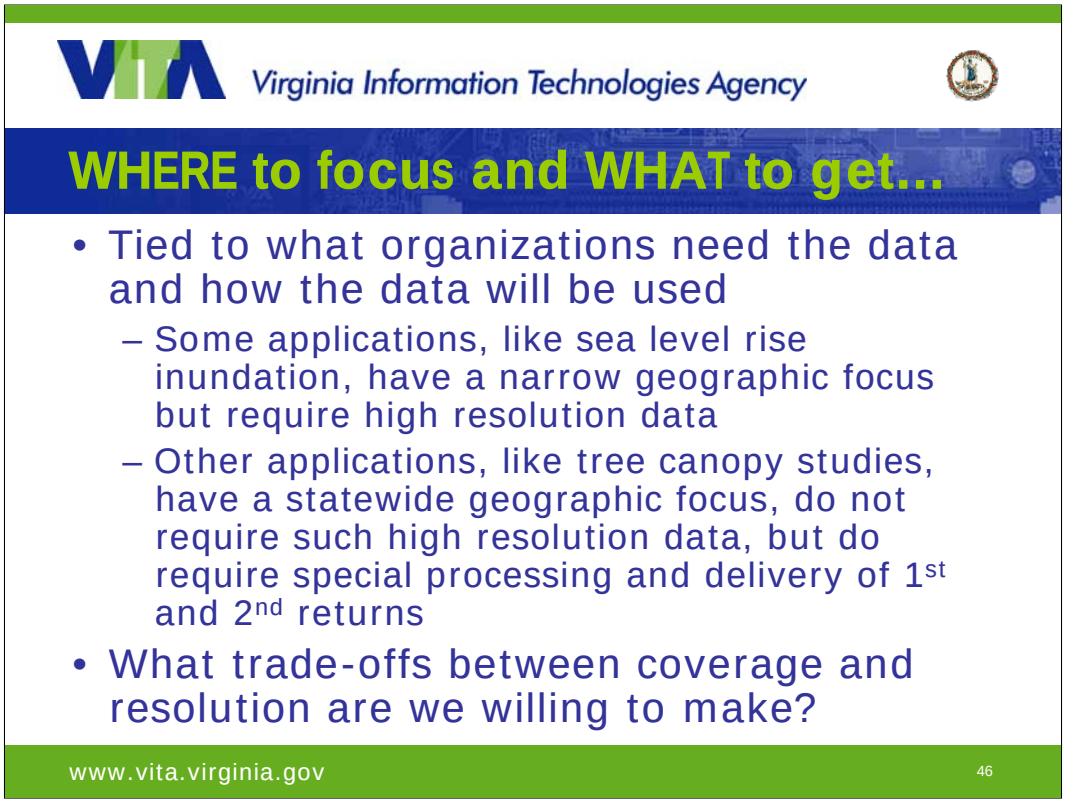
# Very High Resolution Lidar



# Surface Model

# Bare Earth Model

# Lidar Intensity Imagery




Understanding what data products we need and where in the Commonwealth to focus our efforts is key planning a statewide lidar acquisition.

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# Virginia's Coastal Zone


**Virginia's Coastal Zone as defined by DEQ's Coastal Zone Management Program**

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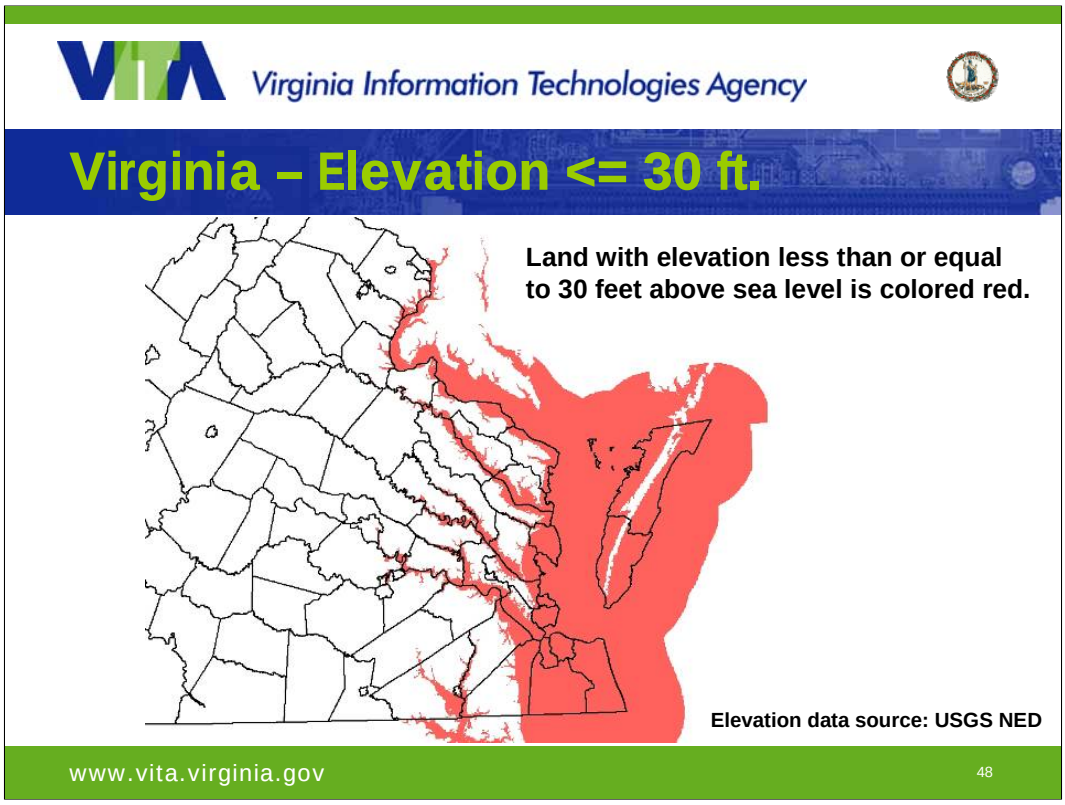
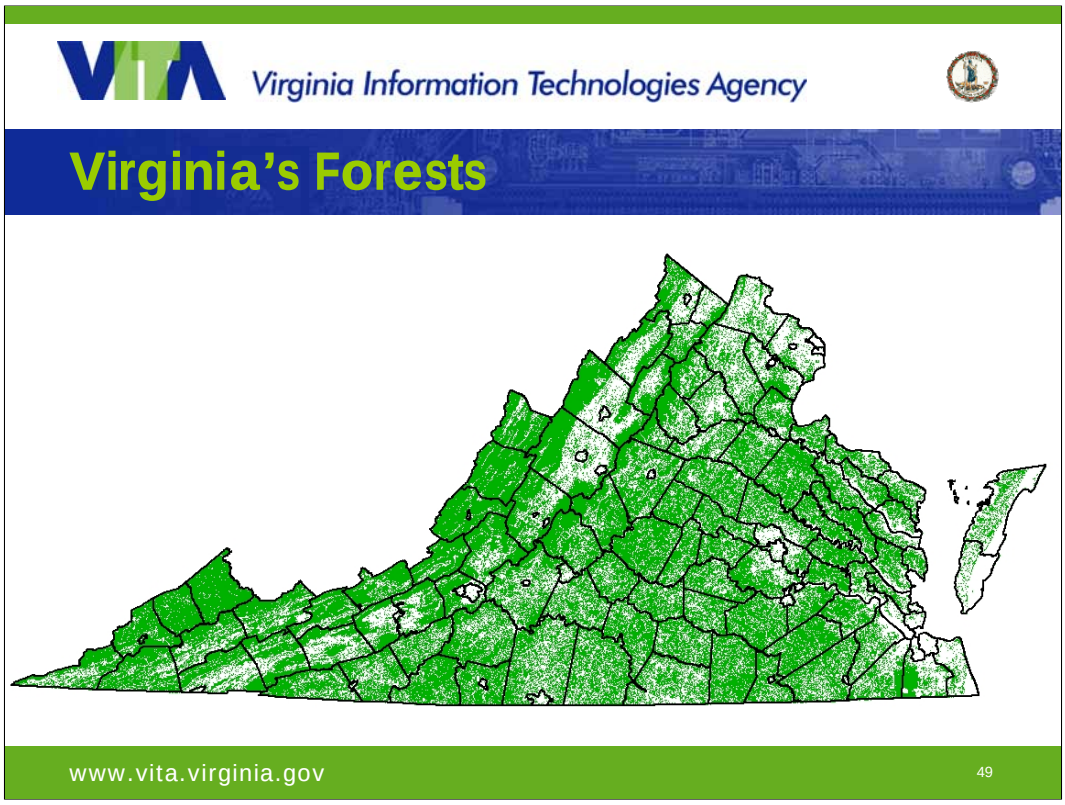
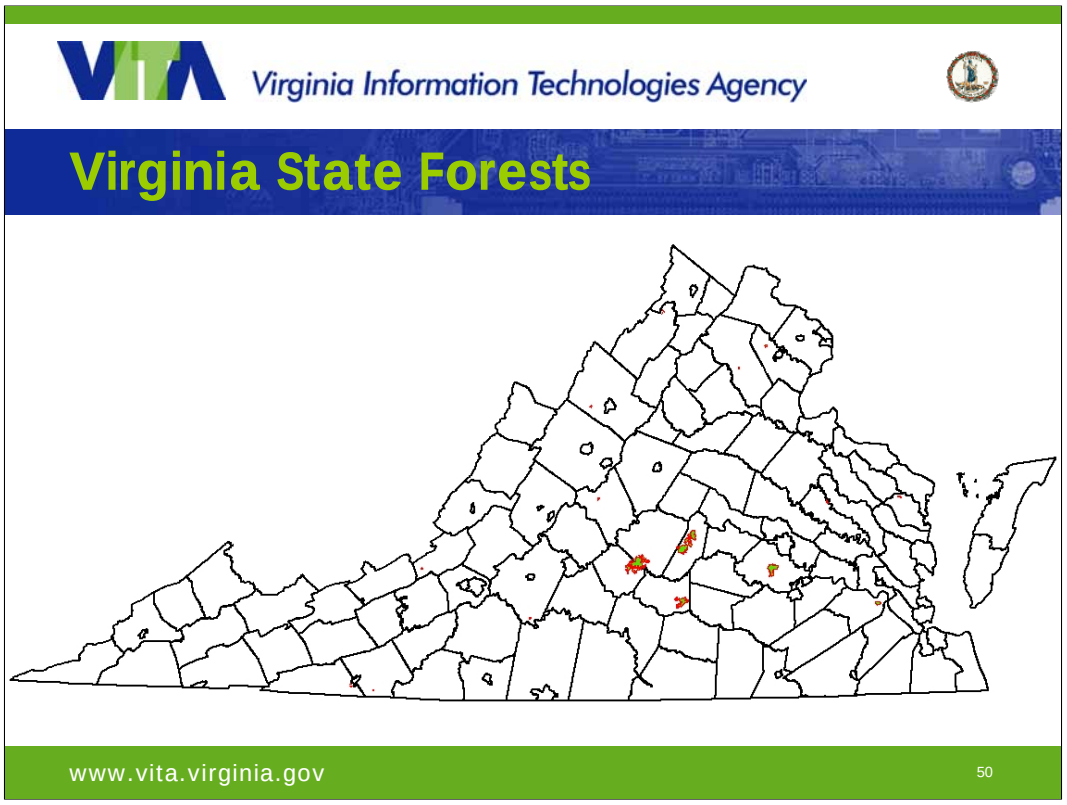
A priority area for high resolution elevation data is Virginia's Coastal Zone (as defined by DEQ's Coastal Zone Management Program).



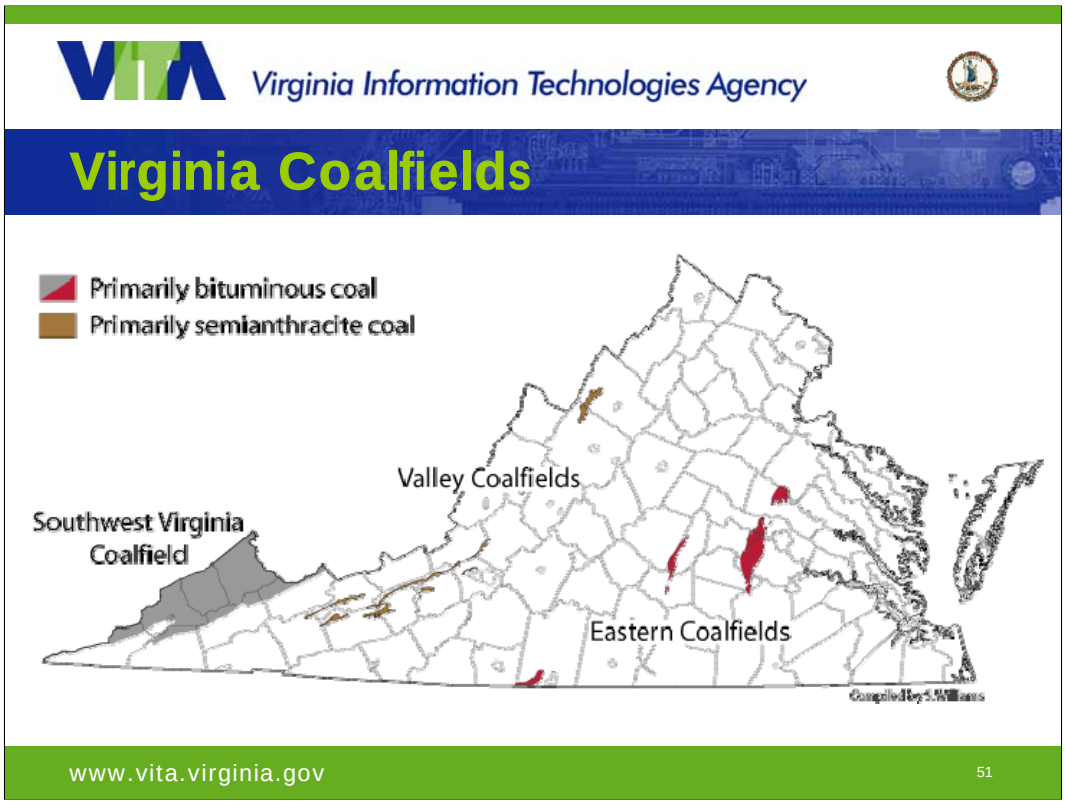

If collection of high resolution lidar across the whole coastal zone is too expensive, is it useful to prioritize the collection of high resolution bare earth lidar by elevation? In this example, we might want to collect very high resolution lidar at elevations less than or equal to 30 feet above sea level (or some other predetermined elevation). High resolution data in these areas would enable modeling of sea level rise inundation and other coastal issues. The rest of the coastal zone and other parts of the state could be collected at a lower resolution.



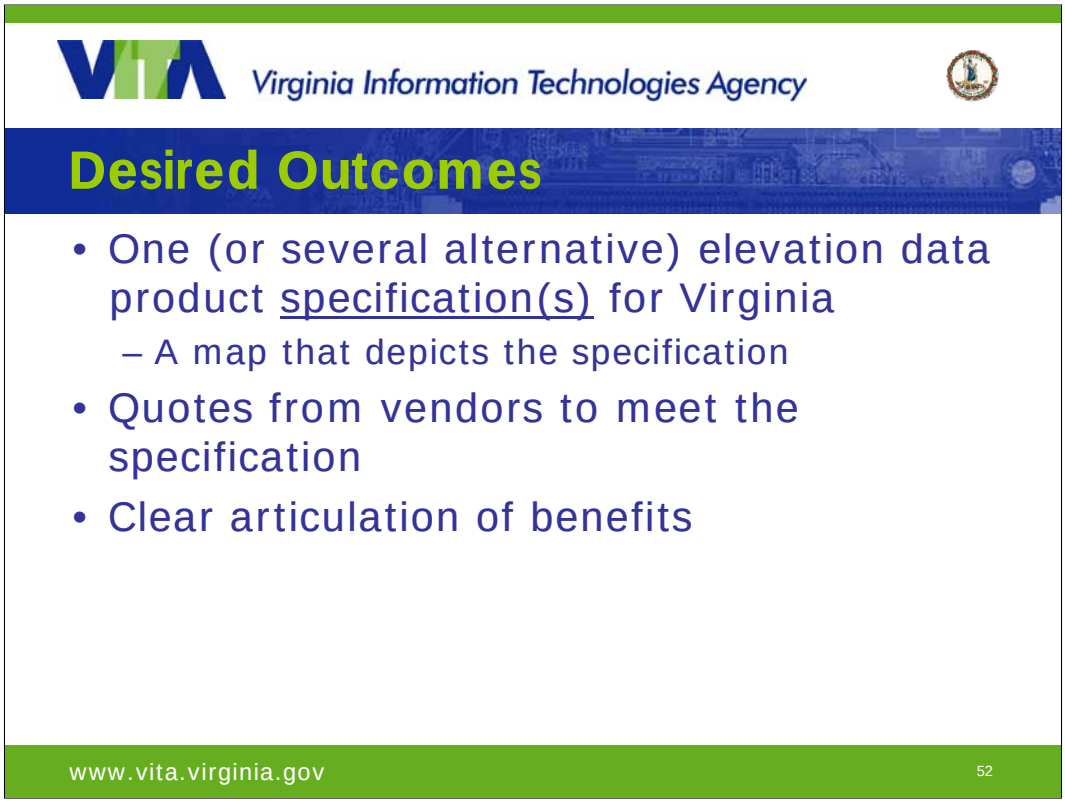

The Virginia Department of Forestry is interested in using lidar for tree canopy studies. Much of Virginia is forested, which is a good reason to collect statewide lidar. We need to determine what resolution of lidar data is ideal for tree canopy studies and if the benefits of collecting and using lidar for this purpose outweighs the cost.




If we determine that collecting statewide lidar for tree canopy studies is not cost effective, perhaps we can collect lidar only over Virginia state forests or for other specific areas that would provide a reasonable sample of tree canopy for Virginia (such as transects of the state).




The Virginia Department of Mines, Minerals, and Energy (DMME) is very interested in high resolution elevation data for geologic mapping. Some key areas of interest in karst landscapes, coalfields, and slopes. Perhaps we could focus high resolution lidar acquisition on these and other areas of particular interest to DMME.




One of the goals of the lidar cost/benefit analysis is to document several alternatives/scenarios for collecting/creating adequate elevation data that meets Virginia's needs. This process entails developing one (or perhaps more) elevation data product specification(s) for Virginia. These specifications would detail what elevation data we need (e.g. bare earth, tree canopy, structures, etc.), what accuracy and resolution is required, and *where* in the state we need the data. We can then use these specifications to get budgetary quotes from vendors to help us determine our most cost-effective option.

As part of this process, we must identify and quantify the benefits we expect to receive from meeting the specifications we design. These benefits may come in the form of cost savings, cost avoidance, revenue generation, goodwill in the community, better decision making, and others.


VGIN needs your help in identifying people or organizations that can help us define Virginia's specification for elevation data (and specifically lidar). What lidar specifications will meet the needs of the Department of Forestry for tree canopy studies? What lidar specifications will meet the needs of other natural resources agencies for sea level rise modeling, flood modeling, microhabitat mapping, etc.? What lidar specifications will meet the needs of transportation professionals, emergency managers, etc.? If you know people who can help, please contact Sam Hall at VGIN at samuel.hall@vita.virginia.gov.

Virginia Information Technologies Agency

# Issues, Input, and Questions

**To raise issues, provide input, or ask questions, please contact:**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